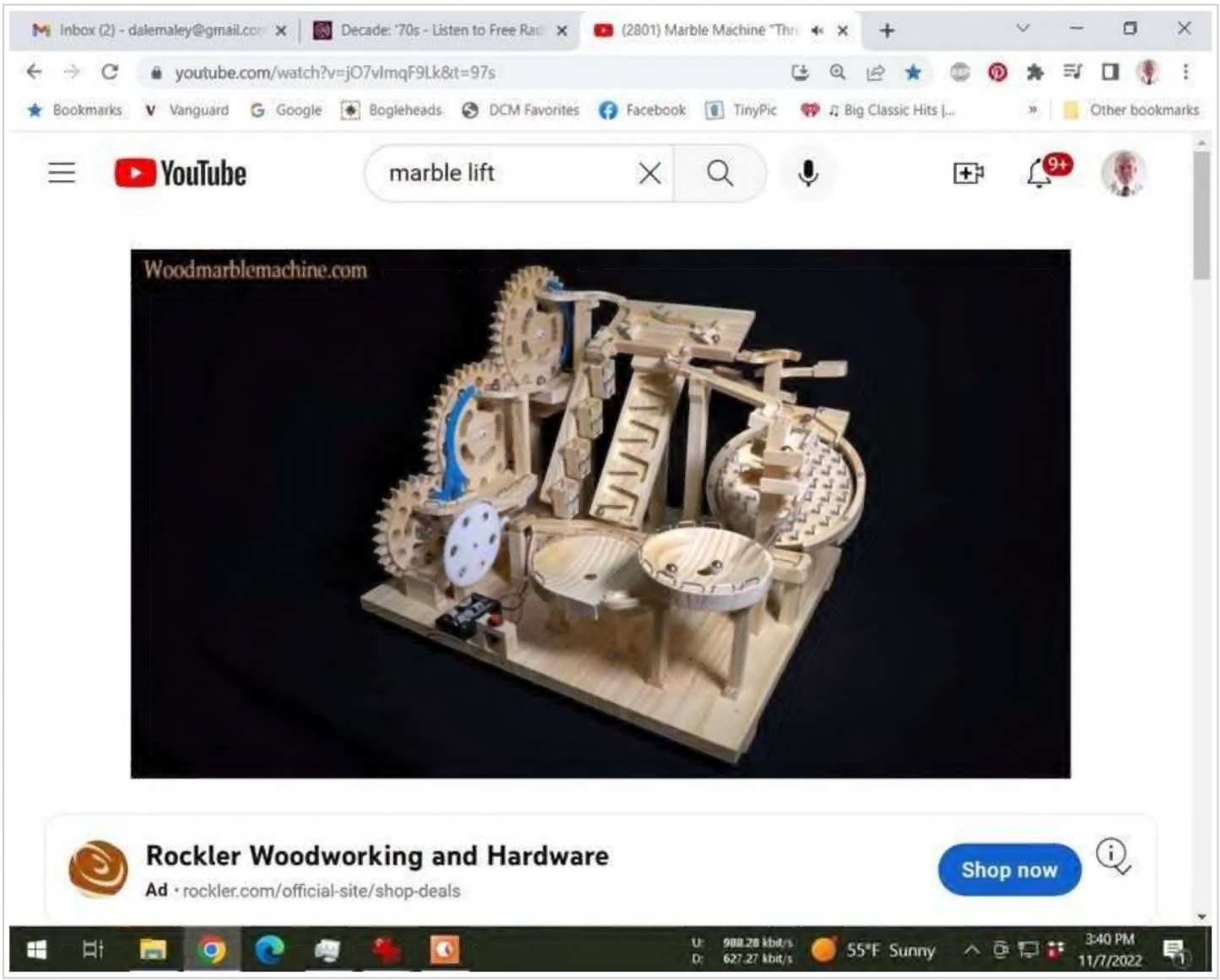
3 Wheel Marble Lift Marble

I have used several methods to lift marbles so they can descend in various fashions. These methods include two 4-bar linkages and the Marble Pump.

One method I have not tried, is where you have holes in a rotating wheel, and the wheel lifts the marbles.

Here is an example from a Youtube video:



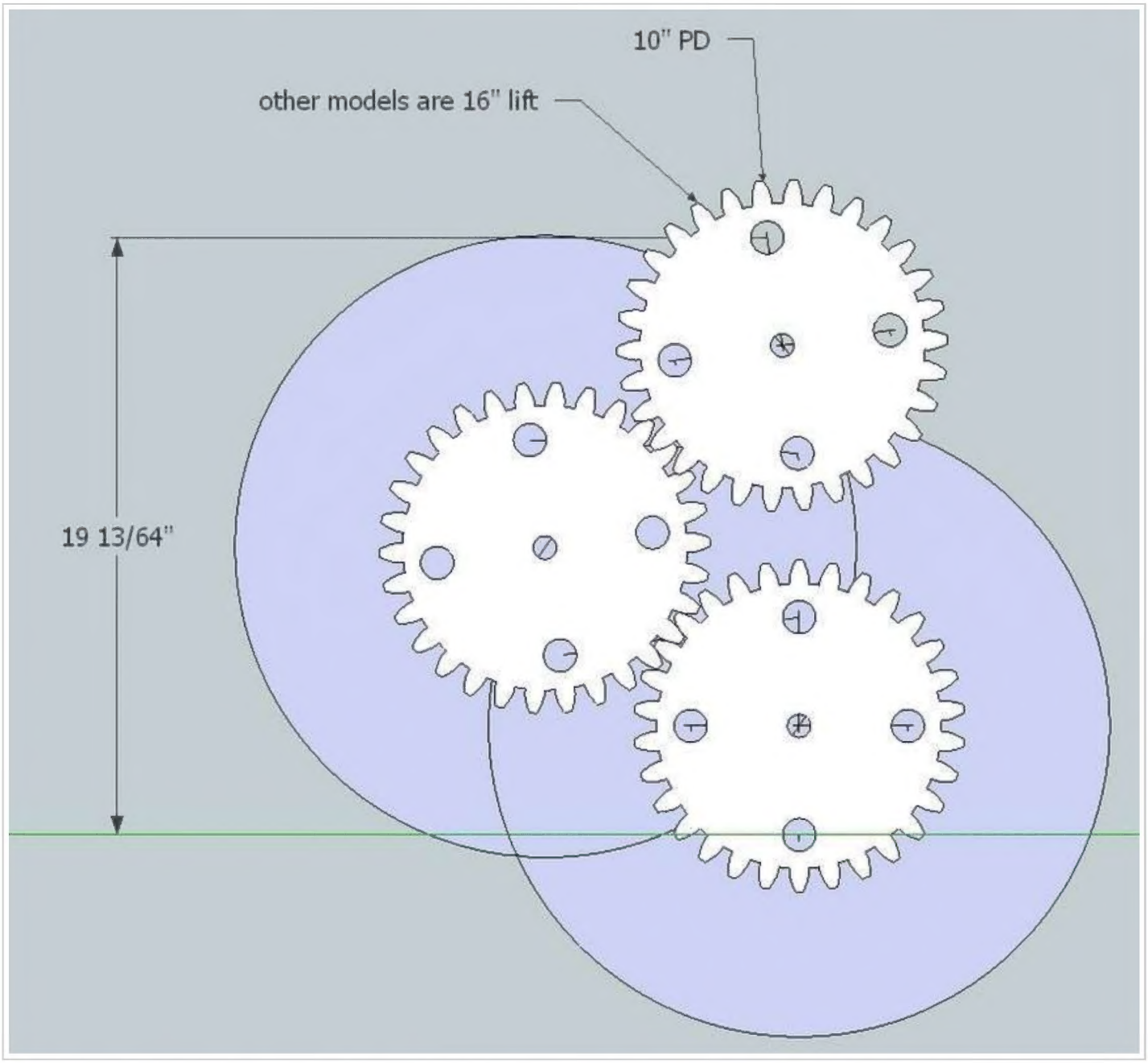
Gear form generator

I am using the free GearDXG.exe program to make the gear outline in DXF, then I import it into Sketchup.

Sketchup

From my experience on other marble lift models, I want about 16" of lift.

In Sketchup, I first tried 3 wheels, each with a 10" pitch diameter. I am going to use 1" diameter marbles, so the wholes in the wheels will be slightly bigger at 1-1/16" diameter.

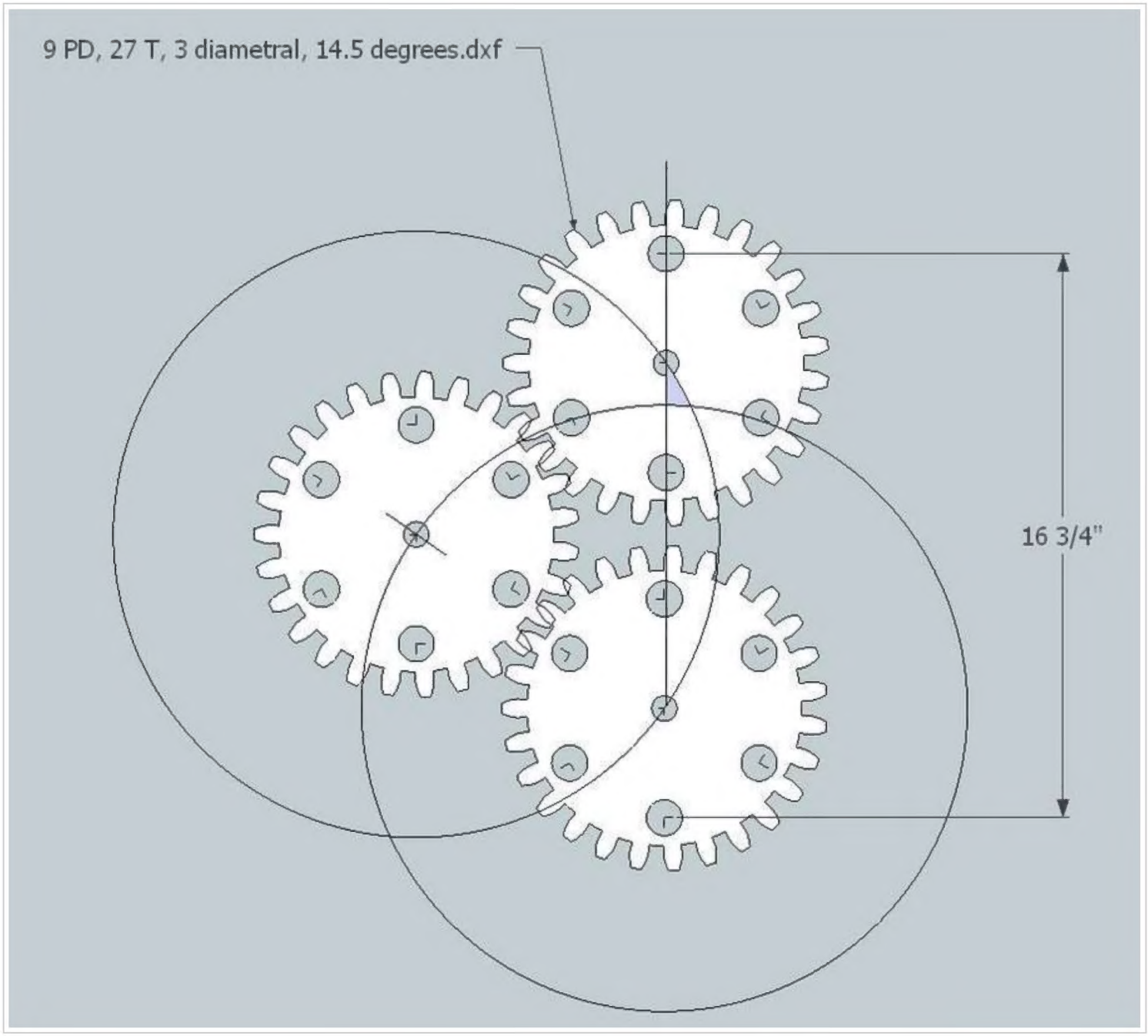


The marbles enter the lowest gear, at the bottom. The crank is on the back side and it will go CW, so in this view the gear moves CCW. The marbles move to the top hole location, then will fall down to the lowest position on the middle gear. They go from bottom to top on the middle gear, then descend into the lowest hole on the top gear, and it takes it to the top. I got about 19" of fall, more than the 16" I wanted.

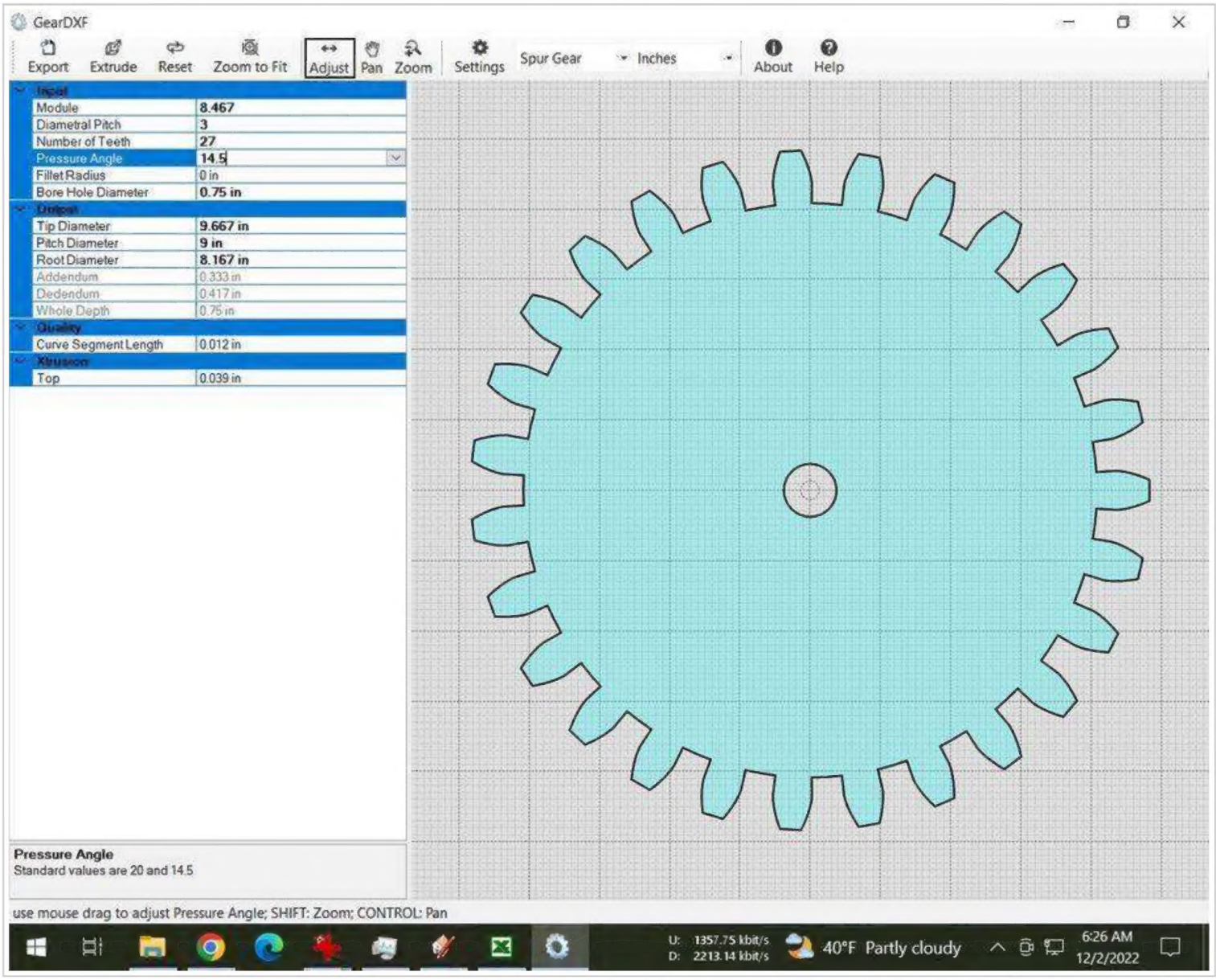
I next tried three gears with each having an 8" pitch diameter.....and I only got 14" of lift, below my 16" targer.

Then I mixed two 8's and a 10" pitch diameter.....and got the same 14" of lift.

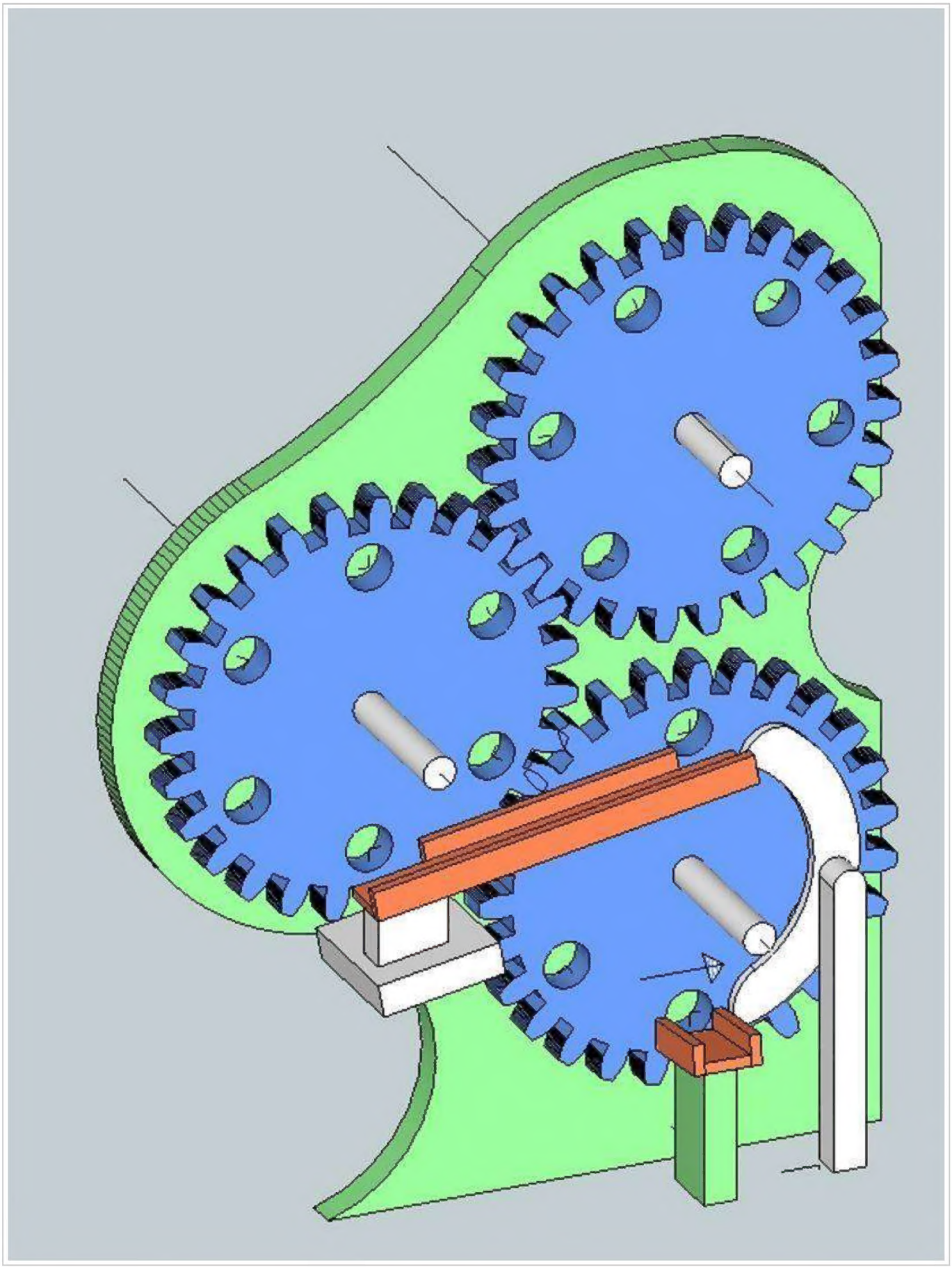
What finally worked was three gears all with 9" pitch diameters.



Big gear design from GearDXF Program



Starting Detailed Design with 3 gears each with 9" PD



Prototype testing

I should build the lower gear, and the back panel, to test out the design.

I think you drill the holes in the gear at an angle, maybe 6 degrees, so the marble enters at the bottom, but wants to exit at the top.

Since kids can crank up to 100 RPM, I do not want the maximum number of holes in each wheel, because that will be too fast of rate of marbles. I will try 6 holes per wheel.

This should be a fun model to play with :)

Drilling marble holes at 6 degrees

I think I will make a fixture to hold the gear with a shim on 1 side to raise the gear so I get the same 6 degree angle.

If the gear has a 9 inch PD, if I put the shim at 4 inches from the center, how thick does shim need to be?

so horizontal part of triangle would be about 5 from left side to center plus 4 more inches or 9 inches.

we know desired angle is 6 degrees, so shim height should be 9 times Tan of 6 degrees..... = 9 times 0.10510423526 = .95 inches

Different gear making process

1. glue up 2 oak boards to give blank
2. band saw slightly larger than gear OD
3. mark center at same time
4. attach blank to lathe faceplate
5. turn OD of gear
6. put 3/4" bit in tailstock of lathe, drill most of the way through on lathe
7. remove from lathe, hand electric drill what is left
8. glue on Sketchup printout
9. scroll saw the gear teeth

hopefully this will minimize run-out in both directions on the gear!

Hole Size in the gears for the marbles

I am going to use 1" diameter marbles.

I normally use my special 1-1/16" diameter Forstner bit to make holes for these marbles.

I got to thinking about it, and 1/16" on the diameter is not much tolerance to allow the marbles to enter the holes in the gears.

I went back to a couple of Youtube videos that used this concept, and they have plenty of clearance in the holes for the marbles to enter.

So, maybe I should go up to 1-1/4" diameter Forstner bit for these holes instead of 1-1/16 diameter?

My drilling fixture

On the drilling angle, I ended up with a 1" high shim over a run of 9 inches, which is about 7 degree angle. Most marble stuff needs a minimum of 3 degrees, so 7 should make marbles load and unload quickly.

I also chose to go with 1.25" holes, to give some tolerance for the marbles to enter the gear.

Making 1st gear

1. Glued up 3 pieces to get red oak blank
2. Bandsawed to 10 inch OD, note this max OD that will fit in my 1939 Montgomery Wards wood lathe
3. Mounted on my biggest faceplate with 4 wood screws
4. Turned OD to get as close as I could to Gear OD of 9-5/8" roughly
5. Mounted 3/4" Forstner bit in tailstock and drilled shaft hole almost thru. Quit because I did not want bit to hit steel faceplate, finished hole on drill press. I could not really check for runout on the lathe, because piece won't fit with 3-jaw chuck on, not much run-out on 3/4 dowel held in vise.
6. Glued on sketchup paper pattern getting outside on OD of gear as best I could
7. Use big bandsaw with 1/8" blade to cut sides of 27 teeth, then scroll saw to cut root line
8. Put in fixture, drill 6 holes, 1-1/4" diameter
9. use wet rag to remove paper and glue, dry in oven

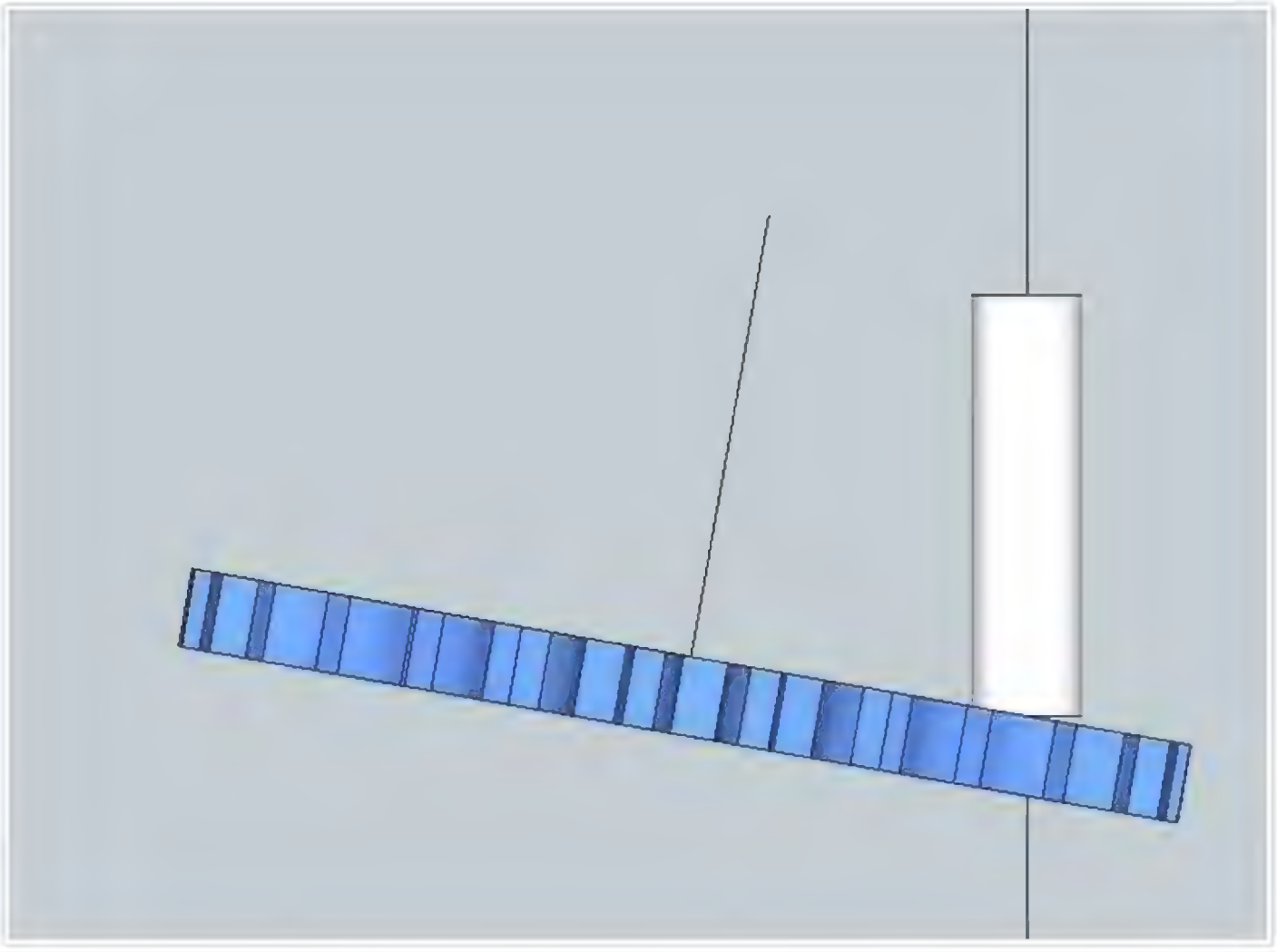
Turning gear OD on lathe

Cutting gear teeth on scroll saw

Making hole drilling fixture

My brain does not work well in 3D, with respect to how to drill the right angle. I did it in Sketchup, to determine the LH side of the gear needed shimmed up, and I drill on the right hand side.

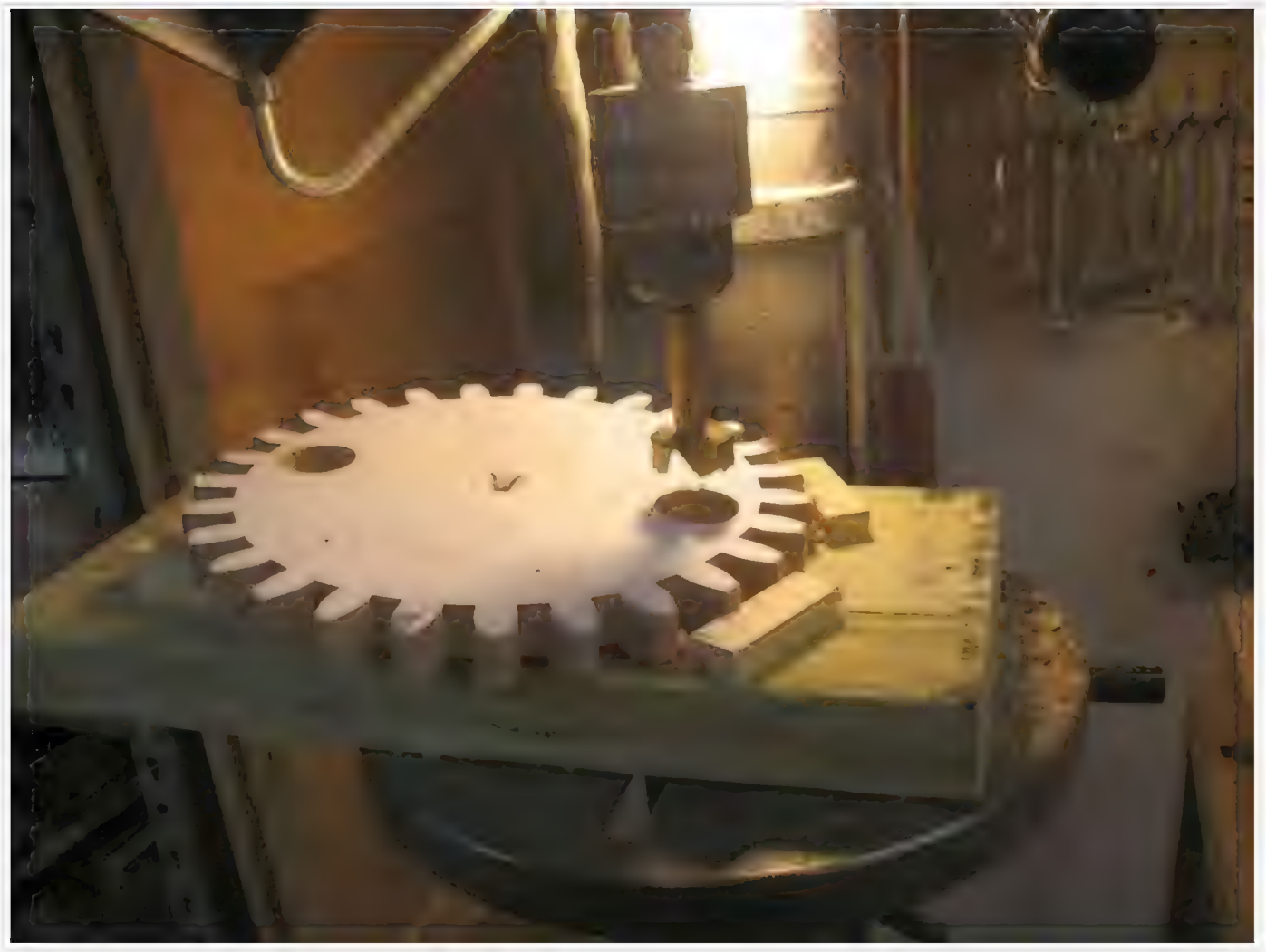
I did some test holes on scrap wood to verify I had it right before I drilled the oak gear.



My wood fixture, has 1" high shim to get 7 degree hole drilling angle


Glue-All


Glue All



Testing 1st Gear

I made a 3/16" thick shim and put it behind the gear, then attached the gear to a piece of scrap wood using a 3/4" dowel. It worked fine with marble entering at bottom, then wanting to fall out at top.

Scrubbed paper and glue from gear, washed, dry in oven

Making other big blanks

Since my little test went ok, looks like my concept is going to work ok.....so I glued up the 2 additional red oak gear blanks.

I also glued up some pine to make the big vertical piece the 3 gears mount to.


DELTA

Increasing rigidity of gear shafts

I have learned from other projects that an L/D ratio of about 2:1 helps keeps gears rigid while turning on their shafts.

For smaller gears using 3/8" diameter shafts, a mounting plate 3/4" thick gives a 2:1 L/D ratio, and works good.

Using a 3/4 shaft on a 3/4" thick mounting plate only gives a L/D ratio of 1:1, and the gears usually wobble too much while turning.

For this project, I added 3" OD spacers behind the pine board, to give 1.5" thickness for the 3/4" diameter shafts which is 2:1 L/D ratios.

The deep reach clamps I made last year really worked nice for gluing on the spacers.

Vertical gear mounting board

I decided to start with it rectangular, then when model is done, I will remove material and add nice curves to it. I may need to mount some stuff to the board, that is why I am leaving it big.

2nd Gear Made

I think my gear #1 blank is slightly oversize on the OD, and gear #2 is closer to nominal 9-5/8" OD.

Determining proper gear center

The distance between the 2 gear shafts should be 9" in theory.....but in the real world you have run-out from shaft to OD of teeth, plus variation in the teeth size.

On smaller gears, say 3 to 6 inched pitch diameter, it usually works out to adding 1/16 to 1/8" to the nominal distance for smooth running gears. But these are much bigger at 9" PD.

I took a scrap 1x4 and drilled 2 holes at 9 inches nominal plus 1/8".....tested gears and way too tight.

for test #2, I increased gear center distance to 9 nominal + 1/4".....and these gears worked fine. I had to dremel one tooth and decrease it's size a little bit.....then worked great. So on the first 2 gears, use 9.25 center distance between gears. I will have to test gear #2 to gear #3 and see if 1/4" also works for them as well.

the 2 gears are a little hard to turn, maybe because the 3/4" dowels are a tight fit in the gears and the scrap piece. If the 3 gears are too much torque, I may have to increase the throw of the final crank handle a little. We will see.....

You can use this link to watch a video of the successful nominal + 1/4" gear axle center distance. I used vise-grips on the dowel to turn them from below.

Design Adjustment

I got nervous the model would consume and produce marbles at too fast of pace for my model. I set up an Excel spreadsheet to take a look at this.

#marbles in first gear	crank RPM	rev's per sec	sec per rev	marbles per sec
6	10	0.166667	6	1
6	100	1.666667	0.6	10
6	50	0.833333	1.2	5
1	100	1.666667	0.6	1.666667
1	50	0.833333	1.2	0.833333
So, just have 1 hole in the first gear at the bottom, then 6 holes per gear on the other 2 gears.				

Kids will probably crank between 50 and 100 RPM, so just 1 hole in bottom gear should slow down the marbles to about 1 per second which should be ok for my model.

6 holes in bottom gear and 100 RPM max kid cranking speed would deliver 10 marbles per second, which is way to fast for my model !!!!!!!!

Adding vertical mounting board

Looking at the design, I will need someway to support the 2 tracks that connect the 3 gears, plus the discharge chute at the top. I decided to add a vertical piece next to the 3 gears. It will be screwed to the base plate, then I ran a 3/4 dowel into the gap between the 3 gears to the big vertical riser plate. So far this is working great for providing a way to mount stuff.

Inlet chute to lowest gear

After I got the inlet chute installed, I tried it out. It loads the marble fine, as long as you don't crank the gear too fast.

I should probably round-over the hole edges using a router round-bit, to make it easier to enter, and see if that improves things.

If I can't improve it, I can tell users that if they crank too fast it won't load and they can see that while they crank.

Won't load at high RPM

Once I got inlet chute and transfer from gear #1 to gear #2, I played with the model.

I also took the first 2 gears to the router table and rounded over the hole edges with the 2nd smallest round-over bit.

At slow RPM, it loads at inlet chute ok and into gear #2 fine.

At higher RPM, does not I load at either place, DARN

Some options include:
-make holes elongated or oval to allow for more time to load
-make a 2:1 speed reduction by adding 6 inch and 3 inch gear on hand crank

I thought the small marble games like this I saw on Youtube videos loaded at higher RPM's ??

Went back to small marble game like mine, and all 3 wheels were running relatively slow RPMS. You can use this link to watch this game.

Looks like I will have to add the 2:1 gear reduction to the crank.

Hard to tell on the Youtube video, but I'm guessing a 1/4 of a turn in 1 sec, which would be 15 RPM or 4 sec per rev.

Boy, if a kid cranks 100 RPM max, I need a 100/15 speed reduction ratio or about 7:1.....so 2:1 won't help much.

On my golfing model, I got a 9:1 ratio.....

If you use 2 gears that have 2" Pitch Diameter and 2 gears with 6" PD, you get a 9:1 speed reduction ratio. The shafts on the 2" input gear and the 4" output gear can not be connected to each other, for this method to work.

I checked my actual golfing model, and I had a 4:1 speed reduction ratio. In my write-up for that project, I calculated I needed about 4 to 1 reduction, so I went with two of the 6" gears and two of the 3" gears.....so 6/3 x 6/3 = 4:1 reduction ratio.

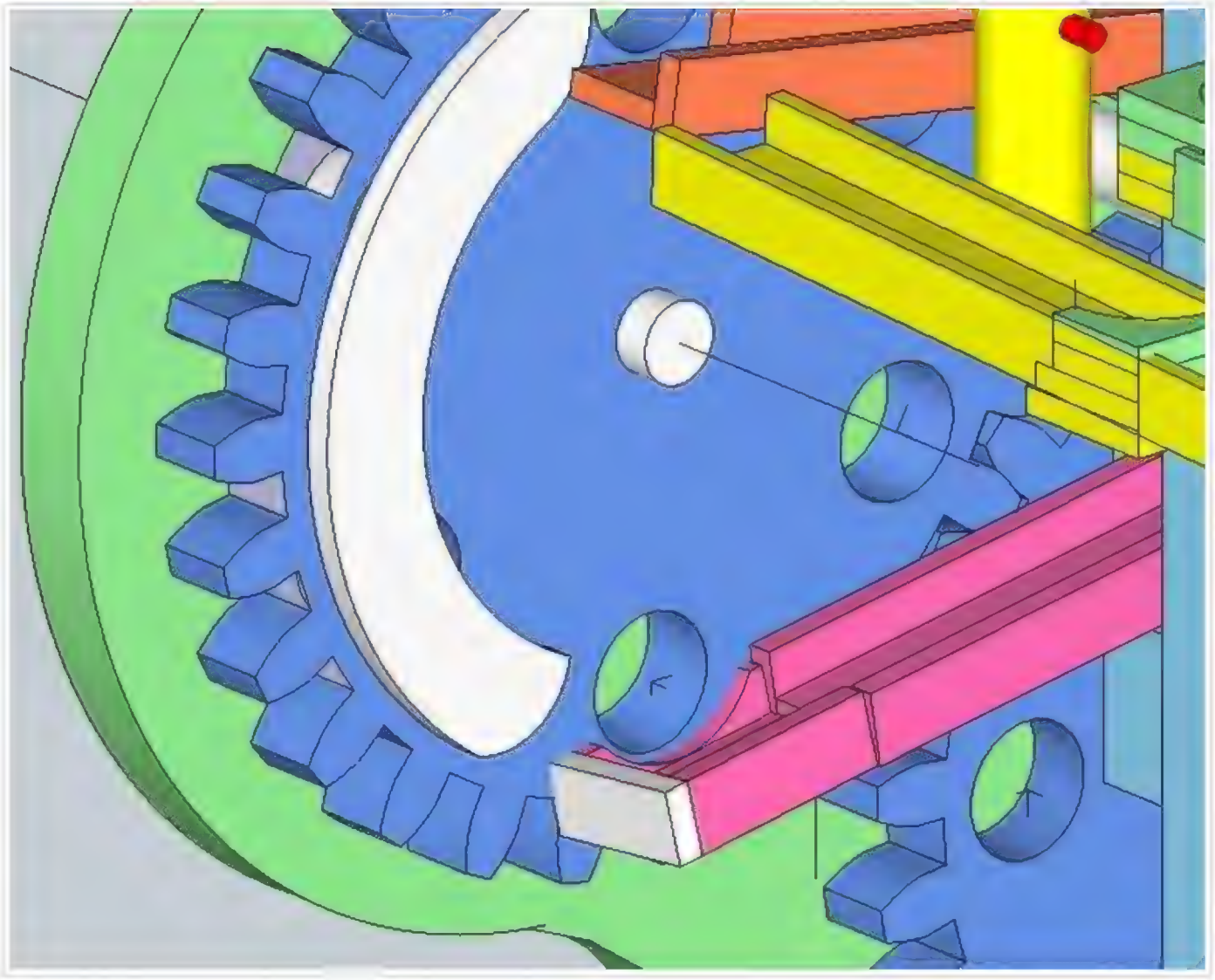
2 inch is getting on the small side for spur gears of wood.

Problem with loader into 2nd gear

I tried adding some tapered shims I cut from standard shim stock package, but the 2nd marble gets hung up.

This is weird geometry, you are trying to have 6 degree fall from gear 1 to gear 2, but then you need another 6 degree fall at a right angle to the chute.

I came up with the idea of making the end a separate piece of chute, then rotate this short piece about 6 degrees and glue to main track. This idea continues the main track 6 degree slope, yet adds another 6 degree slope for the marble to want to drop into the gear. It works pretty good :)



Model Condition at end of day Nov 16, 2022

Not enough time for marble to fall out of gear at top

I first just used a piece of regular track, but there is not enough time for the marble to fall out. Need a revised design, the length is 2.75 inches.

Got all 3 gears working :)

You can use this link to watch a short video of all 3 gears working.

I need to shorten up the LH side of the lower guard to see if that reduces jams at the first loading of the marbles.

Determining Max or Acceptable RPM for 3 big gears

I downloaded a stopwatch app to my cell phone, then set off the stopwatch. I put a piece of blue masking tape on 1 gear, then counted the number of rev's for 6 rev's.

The result was 6 rev's in 38 seconds = 9.47 RPM.

WOW.....this device must be really slow moving to acceptably lift marbles !!!!!!!!

I guessed the other Youtube small marble game was running 15 RPM, so 9 RPM is in the ball park.

So if a kid can crank a maximum of 100 RPM, I need a speed reduction ratio of 100/9 = 11.1

If I run it at 9 RPM with just 1 hole in the first wheel, I only get .15 marbles per sec [per a spreadsheet I made].....which is too slow.

If I make 6 holes in the first gear, then I get a marble every 0.9 sec, or about1 per sec which is about right.

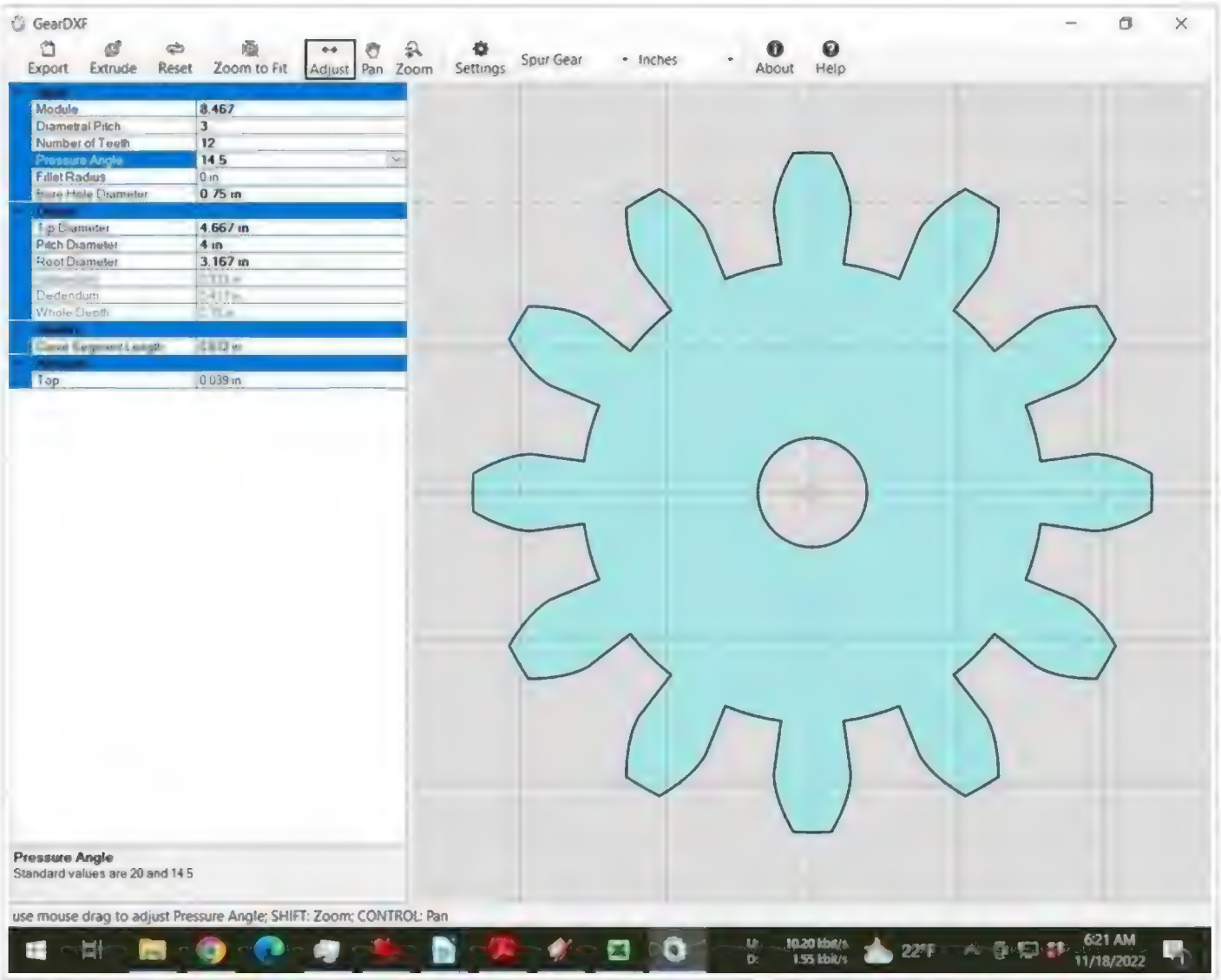
So if I go for a 12:1 ratio, I will need a worm gear set-up to do it. My 4 spur gear set-up on the golfing game only gave a 4:1 ratio.

I did a marble dispensing game with a worm gear. I used standard 1.25" diameter birch dowel for the worm gear.....and a 3" PD spur gear with 8 teeth and a 3/8" axle. This was a 8:1 set-up for the golfing game and I need 12:1 for this model.....so I need 12 teeth.

14.5 and 20 degrees are the 2 common pressure angles for wood gears. I think I will use 14.5 because I think it is more forgiving on the center distance between gears.

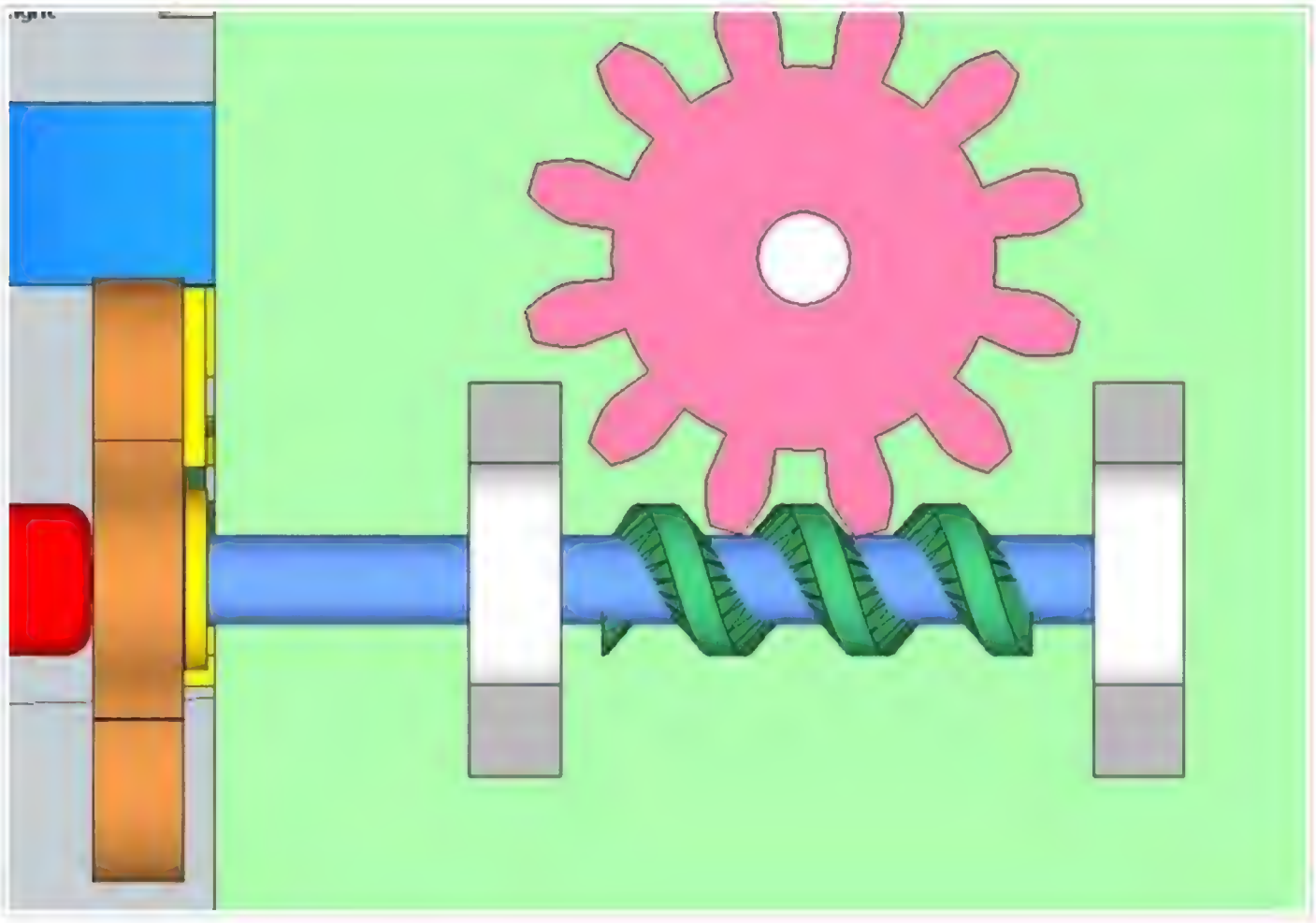
Based upon the amount of torque required to manually rotate the 3 gears, I would rather use a 3/4" versus 3/8" driveshaft. If I turn the worm gear and shaft from an oak blank, then I don't have to worry about the gear depth hitting the driveshaft.

so next step is to package the worm gear set-up into my design.



Worm Gear Diameter

I was going to use a 1.25" diameter dowel to make the worm gear until I looked at it in sketchup.....because I want to use a 3/4" worm gear shaft instead of my normal 3/8" diameter because it takes some torque to turn the 3 big 9 inch wood gears.



Drawing the Worm Gear in Sketchup

I made a Youtube video on how to easily draw the worm gear. You can use this link to watch the video.

Worm Gear

I decided to make a blank about 5 inches long, and with 3 pieces of 2.25 inches pieces.....to make a 2.25 inch square.

After sawing the glued up blank to 4 inches long, I drilled as deep as I could on the drill press using a 3/4" bit Forstner bit. I finished drilling with the block in the vise, and used an auger drill to finish.

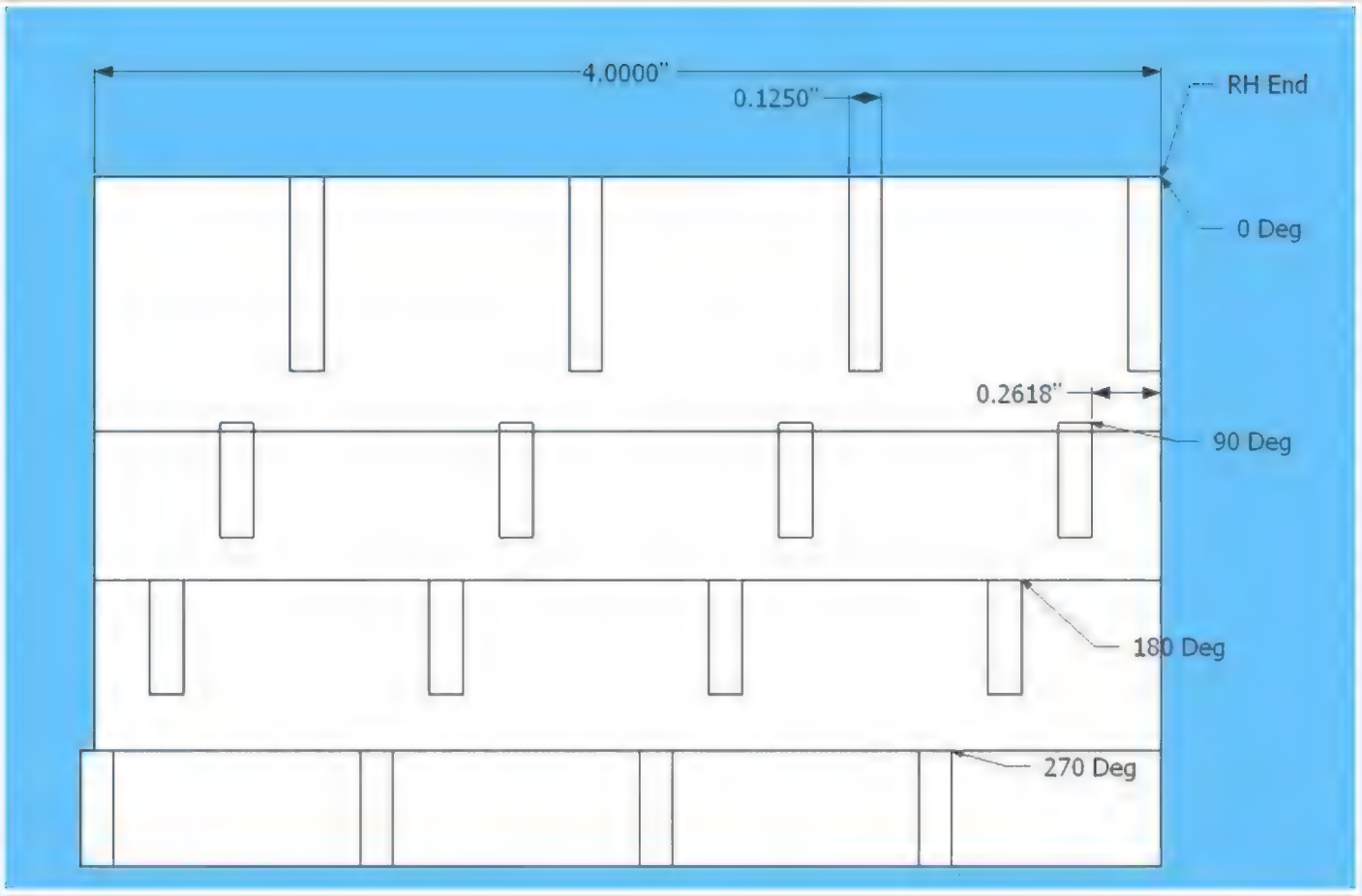
I put a 1" long screw on the LH side of the blank, to keep it from turning in the lathe. I chucked up a short piece of 3/4" oak dowel and slid the blank onto it. I used the tailstock center to help keep the blank oriented.

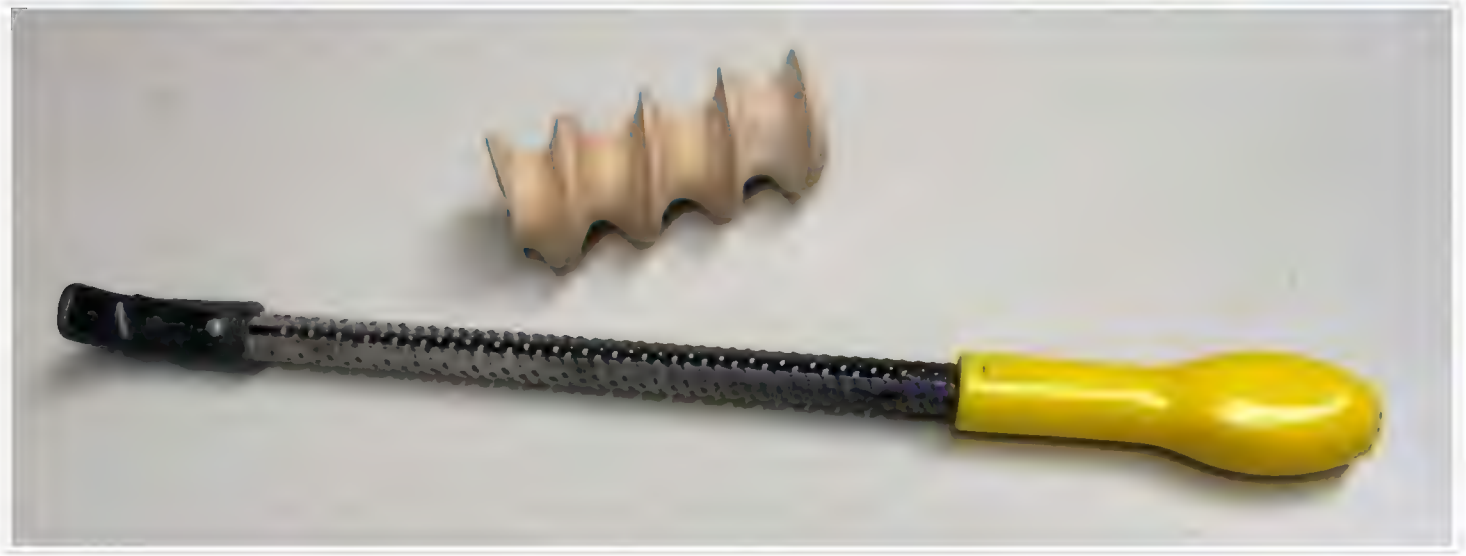
I turned down the RH side to 1.75" OD, then flipped the piece end for end, and turned the other end to 1.75 diameter.

I was then ready to mark the position of the 1/8" wide teeth at the 4 locations at 90 degrees around the blank.

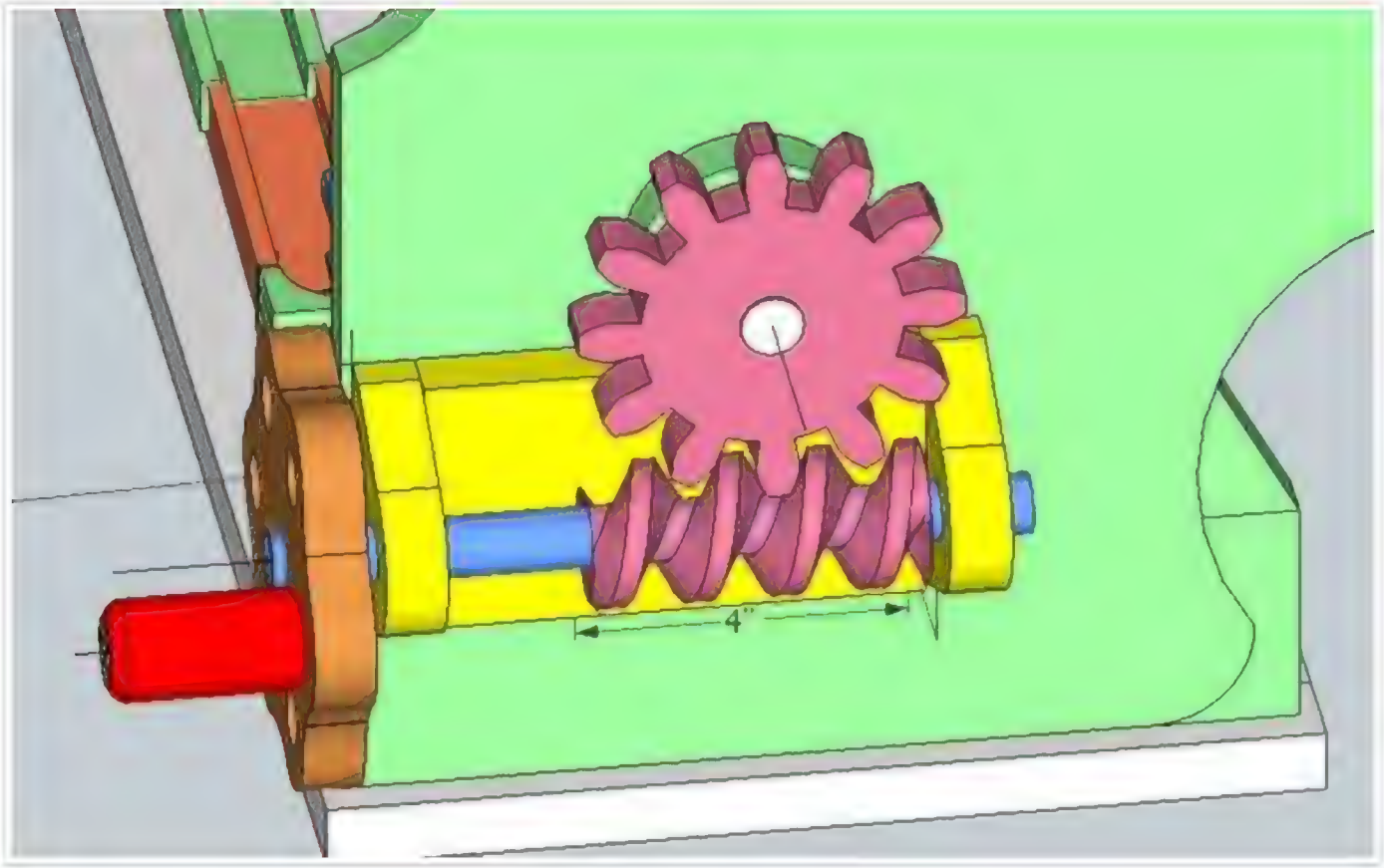
I ended up using a new hand rasp to clean out most of the material.

I previously made a Youtube video showing how I make wooden worm gears. You can use this link to watch it.


4.0000"
0.1250"
RH End
0 Deg
0.2618"
90 Deg
180 Deg
270 Deg



Updated Design for crank and worm gear



Darn Darn Darn !!

I thought I was very careful to make sure I had the correct hand or the worm gear.

I got it all done, and it is the wrong hand!!!!!!!!!!!

I want the crank to turn clockwise when viewing from the front view, and I want the lower gear to turn CCW as viewed from the LH side.

How Did I go Wrong on the Worm Gear Hand?

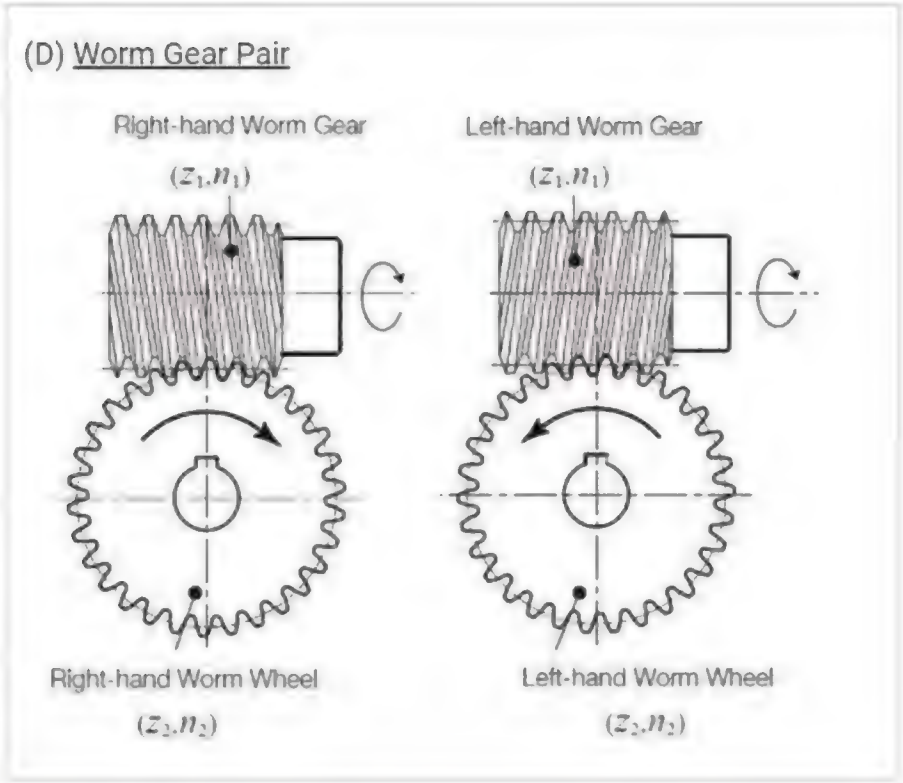
Studying the old chart I used, I realized that chart is for the worm gear above the spur gear. On model, I need the worm gear below the spur gear.

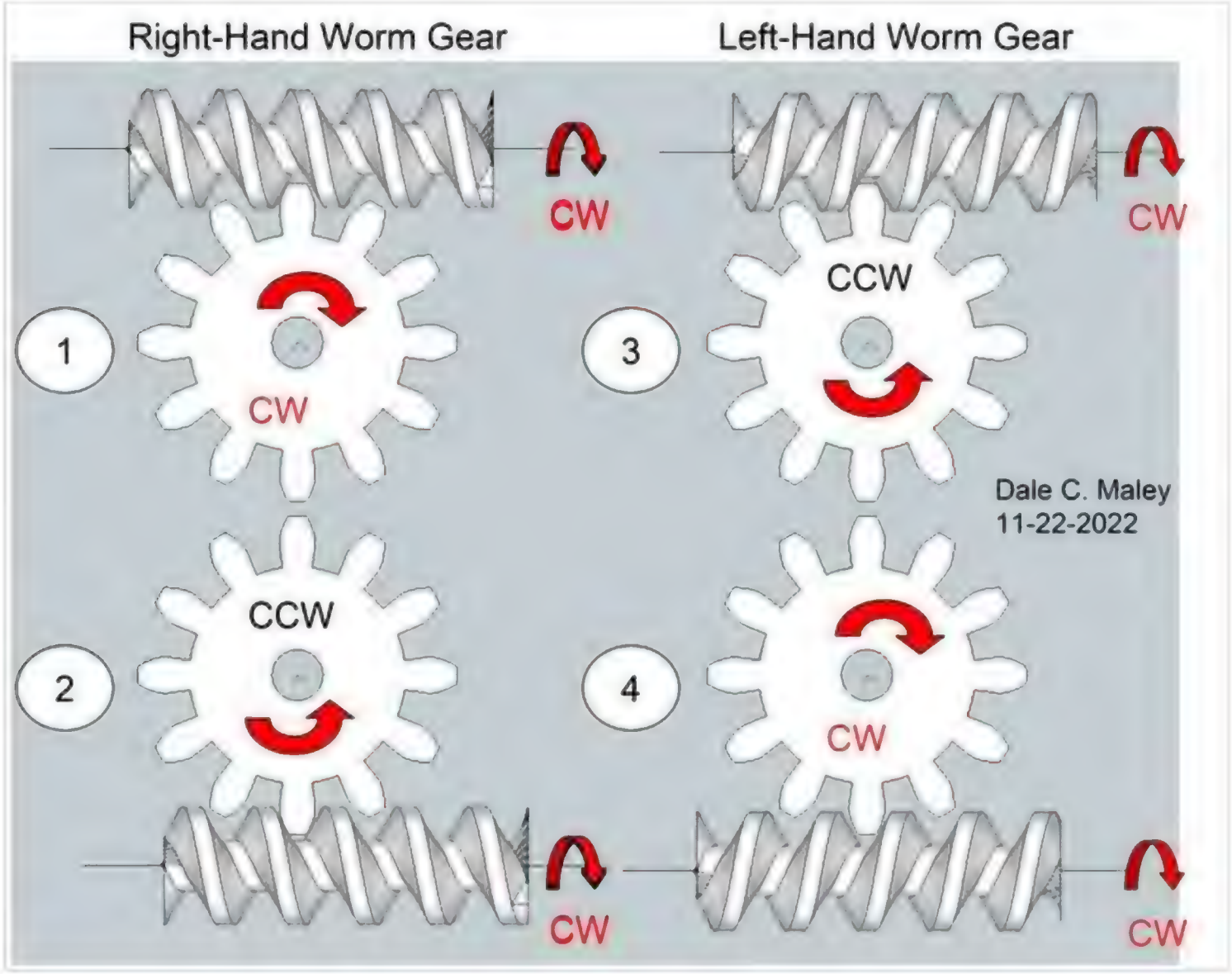
If you flip one of these cases shown in the old chart, the spur gear direction changes to the opposite direction as shown in the chart !!

So I made my own chart. This project is case #2 on my chart.

Hopefully my new chart keeps me from screwing up another worm gear on a future project !!!!!!!!!

(D) Worm Gear Pair





2nd Worm Gear with Correct Hand Installed and Operating Fine

Video of 2nd Worm Gear working ok

You can use this link to watch the worm and spur gear set working fine.

Video of 3 big wheels lifting marbles powered by hand-cranked worm gear

You can use this link to watch this video.

Everything is working pretty well. I made the initial load chute wider when I was turning the big wheels too fast. It jams up now, so I need to take it back to a plain chute like I started with.

I also need to check for any "rough spots" that take more torque on the crank than normal. I can remove the top 2 big gears to help troubleshoot this.

Note: the 12:1 gear reduction seems to work fine, no issues with not loading marbles because big wheels turning too fast. Also note on the video the marbles are coming off the top gear at about the right rate.

Model State at end of day November 25, 2022

Bowl Turning

Since I had to make 3 of these, I worked on my process to improve it also.

1. On blank, dent center

2. Make 3.5 inch dia circle to center the smaller 3" OD faceplate on, to screw it in with 1 inch long screws.
3. Mark blank with 6 inch diamer
4. Band saw 1/4 wider than 6 inch circle
5. Mount on 3" OD faceplate using 4 screws
6. Put in lathe, mark center with about 1/2" diameter circle with pencil
7. remove from lathe, use awl to mark center.....in the center of small circle drawn on lathe, mark 6" OD and also mark 5" circle which gives the 1/2" wall thickness at top
8. Turn OD
9. Turn ID, but not too deep to hit the 4 screws
10. remove from lathe, remove from faceplate, drill 1-1/16" center hole
10a. Reverse the jaws in the 3-jaw chuck to be able to grab OD of bowl
11. Chuck in lathe with 3 jaw chuck, turn ID down to final size
12. Sand OD and ID in lathe

Conserving marble drop height

I did not realize it until I got into the build aways.....you need to maximized your drop height.

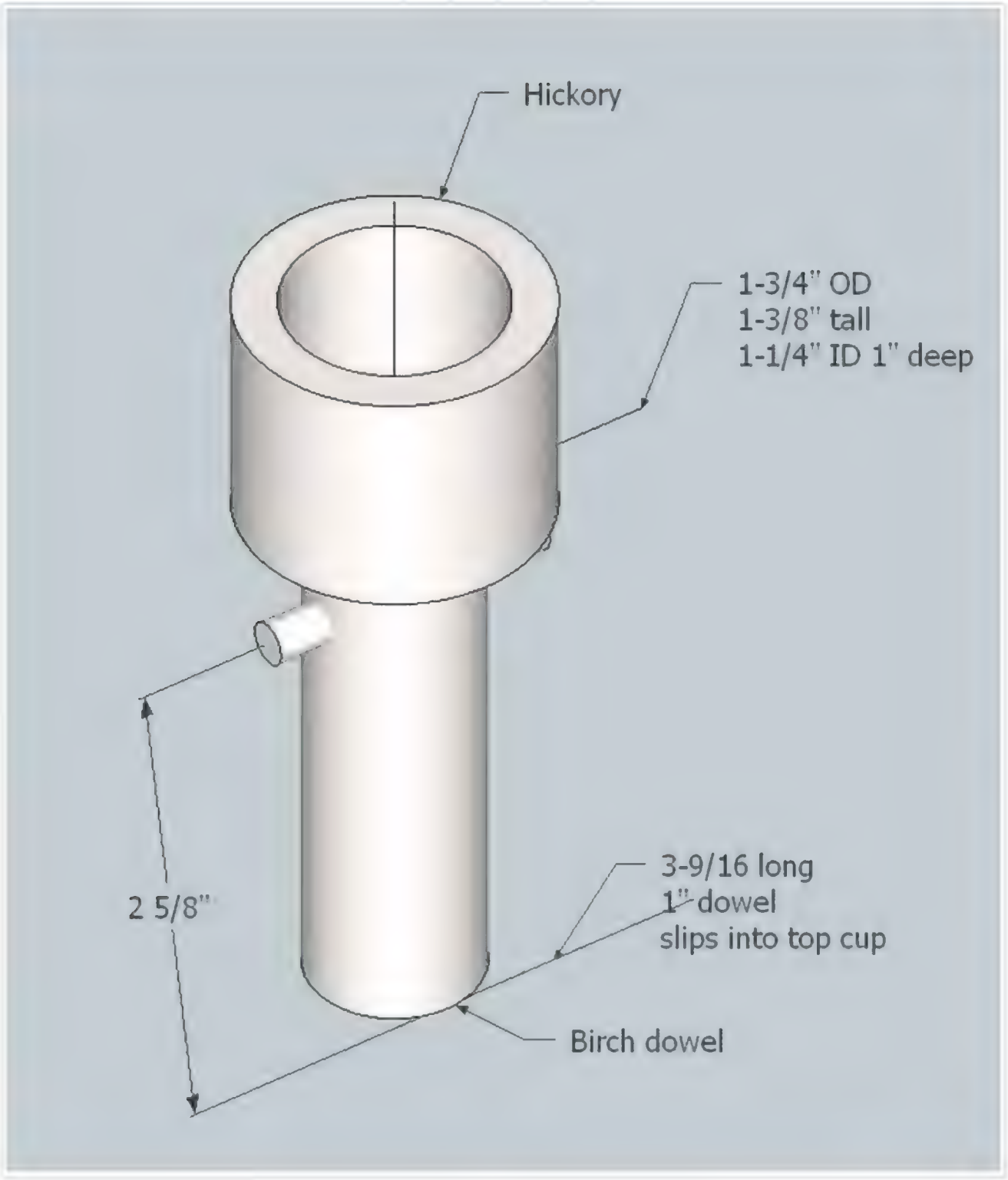
I made the standard assy for the bottom of the bowls, but instead of adding track onto the chute end like my drawing, I set it down on top of the track and glued it to the track.
Bad move, wasted about 11/16" drop height doing this, will redo and follow my print.

Also, do 3 degree runs, not 6 degrees, lot of wasted drop height on a long run using 6 degrees.....about an inch on a 17 inch run.

Installed discharge chute wrong way on 2 bowls, wasted drop height

Flipper trouble

On the last flipper I made, I have trouble with the marble not going in the hole maybe 1% of the time.....so for this project, I redesigned the flipper and made the top cup for the marble a little bigger.



I had a round piece of hickory big enough to make the top cup, so I made that on the lathe.

I drilled a hole for the bottom 1" birch dowel to slide up into the bottom of the hickory cup on the drill press.....I used my special 1-1/16 Forstner bit thinking it would give a little clearance for the 1" dowel to fit nicely. OOOOPS, both my birch and oak 1" dowels are actually a tad smaller than 1" so my fit was too sloppy. I took a short piece of 1.25" dowel and turned the top end down to fit my hickory cup.

But when I tried it out, the flipper was top heavy, and the cup rotated and stayed down, instead of returning to the top!!!!!!!!

I did an excel spreadsheet to see if the top volume was smaller than the bottom volume below the 1/4" dowel pivot.....and the top volume was less than 2% smaller. I'm guessing my hickory is much denser than the birch, that is why it is top heavy.

I drilled a 1/2" hole in the bottom of the birch dowel and filled it with scrap stained glass lead, and hid it with a short 1/2" dowel, and now it is balanced ok. Boy, the things you run into on these projects!!!!!!!

Shortening Height on first two bowls

Long Wiggle Waggle section

Had to move location of 2nd divider block

It would not fit on the same vertical riser as the 1st block, so moved it to the left and added another vertical riser.

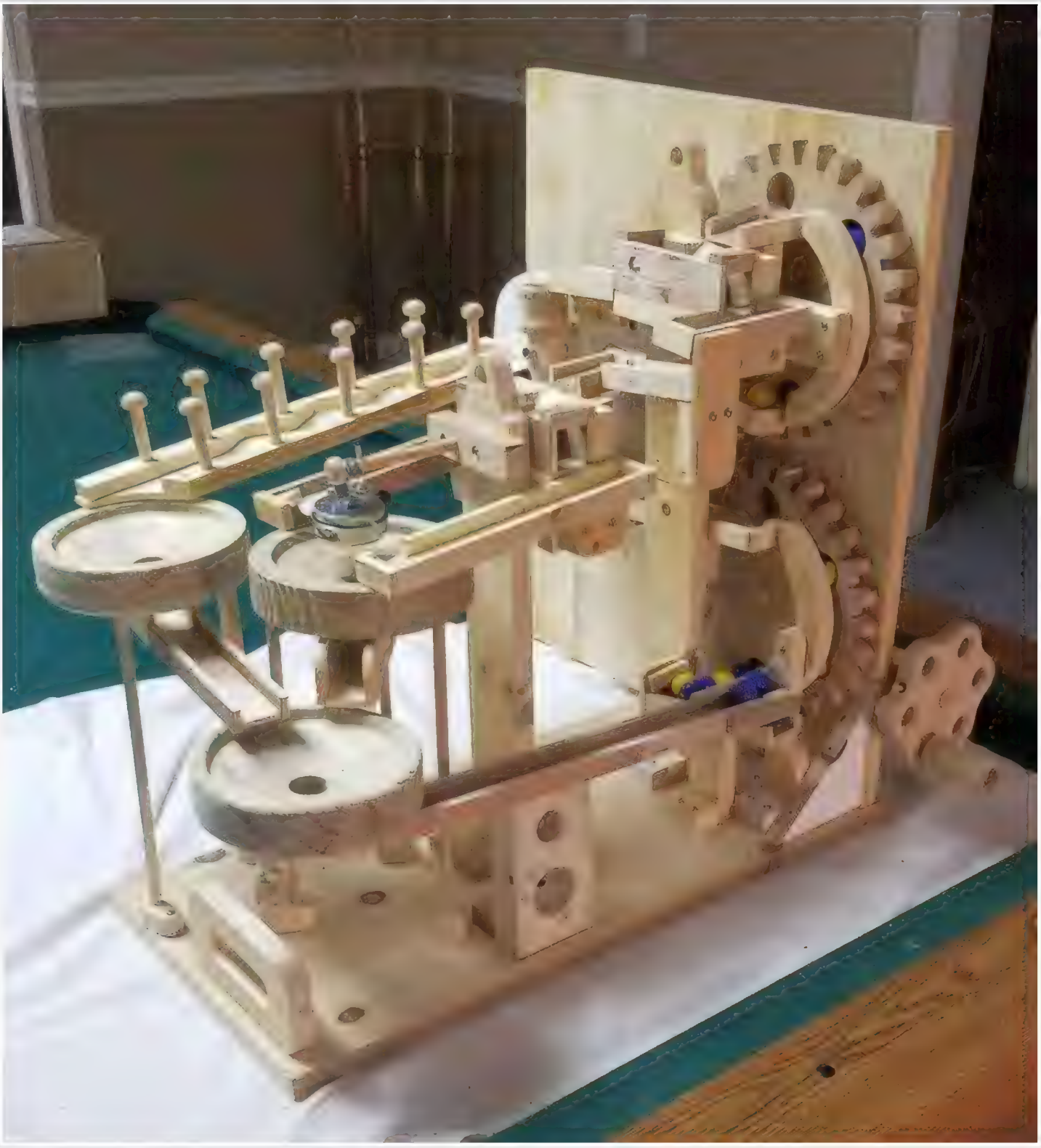
Removable Bell

The grandkids love the bell ringing sound, but my wife gets tired of it.....so I came up with a simple design where you can unclip the bell from its dowel hanger. It only fires on 1/4 of the total marbles going through the game.

About Ready to Stain/Paint the Assembly

Just a few things left before dis-assembly and stain/paint the parts.

1. Remove excess material from base.
2. Remove excess material from vertical base, which will also make it look prettier
3. Add handle on back of vertical base.



Video of Model in Action

You can use this link to watch a video of the model in action.

Smoother running worm gear

I still wasn't happy with the worm gear set in that it seemed to take too much torque to turn compared to other sets I have built.

When I dis-assembled the unit to get it ready for final modifications and then stain/paint, I stripped it down to just the worm gear set and the 3 big wheels/gears. I studied the worm gear set using a light, and I had the proper vertical spacing between the worm gear and its upper mating spur gear.....but there was a lot of friction on the spur gear teeth.....and to the feel, they were not "220 grit" smooth.

I took off the spur gear, and my 1" drum sander on the drill press would fit between the teeth ok, so I sanded with 220 grit between every tooth.

When I put the worm gear set back together, VOILA.....it ran very smoothly with no catching anywhere !!!!!!!!!

Technically, the spur gear teeth should be angled to match the angle of the worm gear, but I don't know if I can make angled teeth on the spur gear or not. I would have to set up an experiment to see if it can even be done or not (possibly tipping the scroll saw table at an angle).

Dis-Assembly

I had several tasks I had to do during dis-assembly, then on to stain/paint.

One of those tasks was to glue up the 3/8" dowel legs on the 2 bowls. To keep the glue from gluing the leg bases to the main horizontal plate, I inserted plastic pieces between the screw mounting feet and the horizontal base. This method works well.

Cut-out on horizontal base

Before I started dis-assembly, I marked in some curves on the back of the model, in the main horizontal plate.....to reduce weight and make a more attractive model. I will cut out the curves using the band saw.

Cut-outs on main vertical base

I initially made the big vertical base rectangular, because I did not know where I would mount everything. My plan was to build the model up using the rectangular base, then when done, figure out where to the cut-outs. I was able to make the cuts on the band saw, even with the 3 round bearings for the gears on the bottom side.....I just had to hold the base at the right angle in the bandsaw.

Lot of pieces in this model !

Big Gear Run-out

At this point, I had the short 3/4" dowel axels glued to the 3 big gears, so out of curiousity sake, I wanted to check the run-out of the OD of the gear teeth to the center. I drilled a 3/4" hole in a piece of plywood, then dropped in the gear and axle into the hole. Using a pencil, I drew a short line outside a tooth on the plywood for the longest tooth, and then for the shortest tooth. The distance was 1/8". In machinist's terms, this would be a Total Indicator Reading or TIR of .125 inches. As a Percent of the OD, it would be .125/9.667 Tip diameter = 1.29%.

For my old 1939 Montgomery Ward wood lathe, 1/8" TIR on a big 9" PD gear is probably not too bad. I have some slop in the headstock bearings also, they are not perfect.

I could try sanding the OD of the teeth to reduce the run-out even more, by putting the sanding drum in the drill press, then clamp the plywood to the table, and carefully rotate the gear. I often do this on gear sets that I did not make the OD on the lathe (I scrolled the teeth including the OD).

I checked the other 2 gears, and they were between 1/16" and 1/8" TIR, not too bad :)

I decided to sand the OD's on my drill press. I set the amount of sanding based upon the smallest OD tooth.

Sanding OD of teeth on drill press

I clamped the plywood piece to the table, then using 2 spacers, set the big gear on the 3/4" axle dowel.

I rotated gear until I went to smallest tooth, then slip drill press table against the sanding drum, then locked the table. Holding the gear by hand, I got it between teeth so no contact of drum and wheel at drill press start-up. Turned on drill press, then slowly rotated gear until 360 degrees done.

I had essentially 0 TIR or run-out on all 3 gears when I got done.

I made a video showing that I could easily drive all 3 gears with 1 finger after I got done.

You can use this link to watch the video.

Reduced Load on Worm Gear set

Since I removed weight from the 3 big gears by drilling 3 gears x 6 holes each (1 1/16" DIA).....and optimized the gears by reducing run-out on the OD to almost zero.....this reduces the load upon the worm gear set driving the machine.

About only other thing I could do is try to make tapered or angled teeth on the mating spur gear. I will stain/paint the model and put it back together as is and see how it runs. I can always run the angled spur gear test at a later time and swap gears.

As-Built Drawings

When I was doing the dis-assembly of the unit, I measured various features including the curved cut-outs, then adjusted my Sketchup drawing to reflect the as-built condition.

Red Oak part finishing

1. Sand parts to 220 grit

2. apply Cherry oil based stain
3. apply Shellac (is thin and dries in 15 minutes versus 2 hours for polyurethane)

After stain/Shellac, gear sets worked great

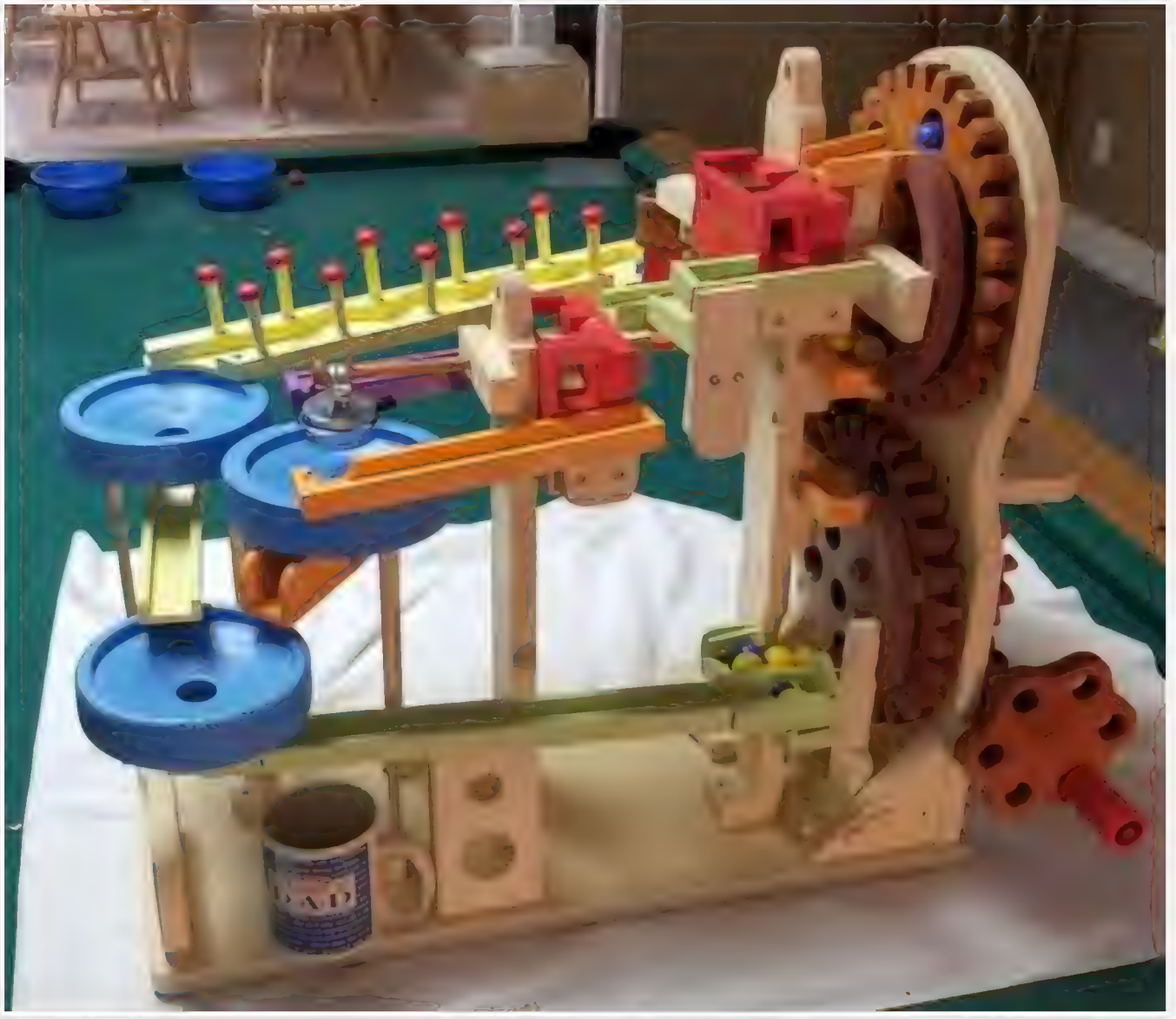
I installed the 3 big gears and the worm gear set. With no load (no marbles in gears), worm gear set and big gears ran very smoothly. No need to make a curved tooth spur gear, except for fun and experimentation.

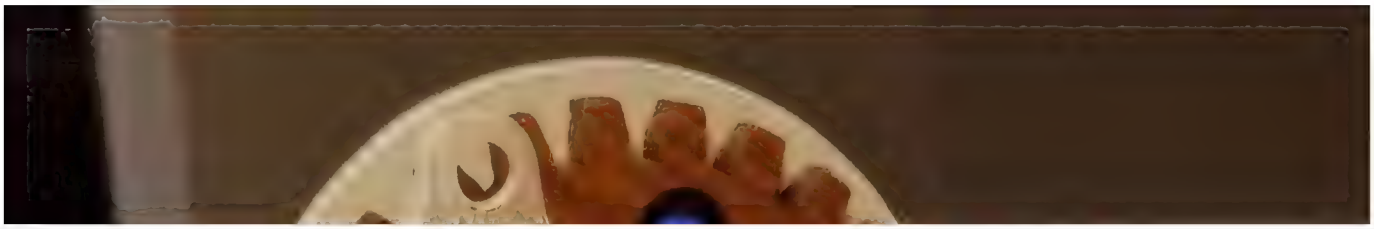
Re-Assembly after stain and painting parts

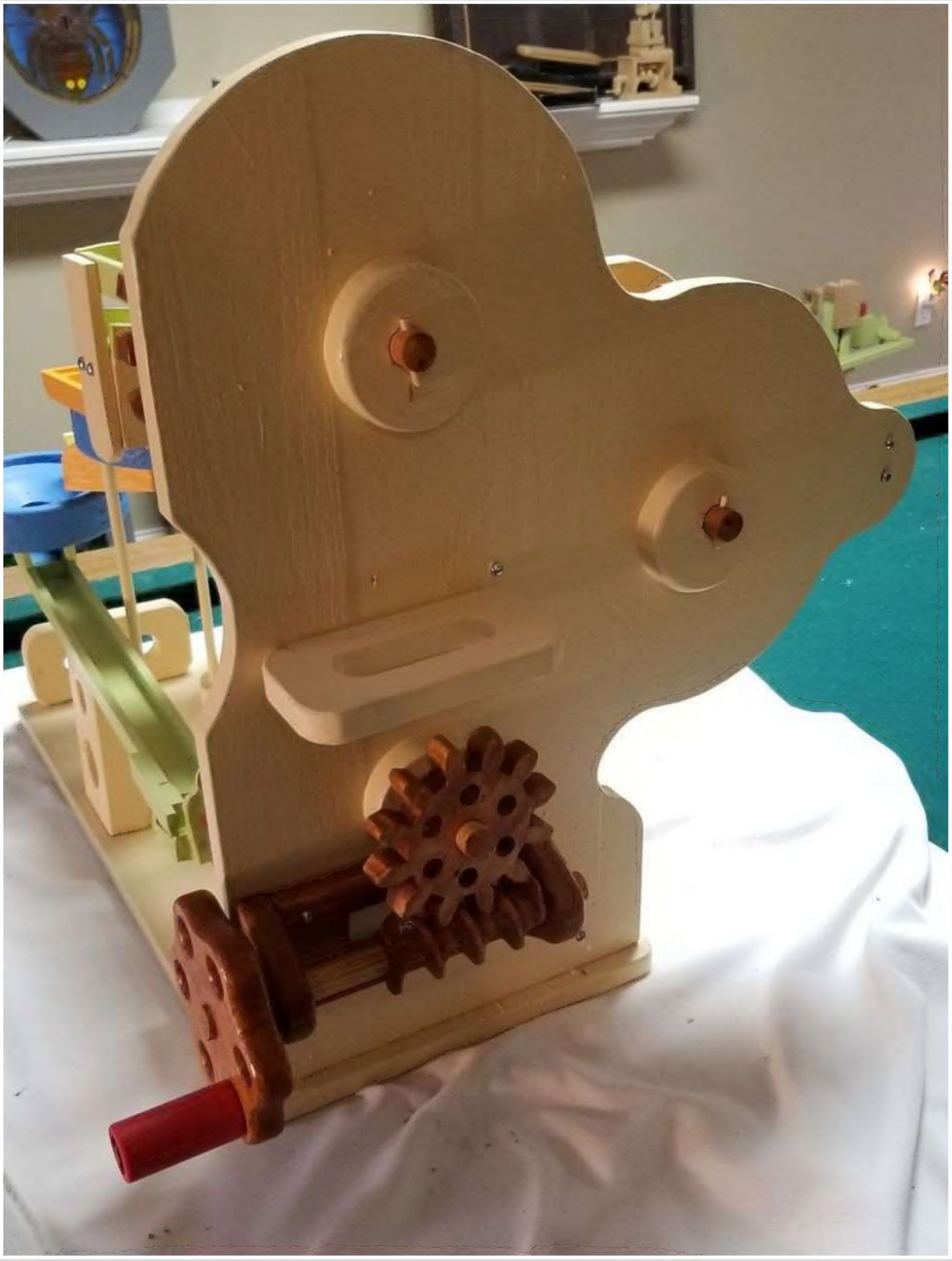
Sketchup Warehouse

I uploaded my model to the Sketchup warehouse. You can download it using this link.

Photos of Finished Project







Youtube Video of Model in Action

You can use this link to watch a video of the model in action.

Closing Thoughts on This Project

It is a good thing I did not keep track of how many hours I spent on this project :)

Some things I learned on this project:

1. The hole in the gear method of raising marbles is relatively simple, but it only works at very slow speeds, like 5 to 10 RPM. Faster than that, and marbles will not load or unload properly. I had to use a 12:1 worm/spur gear reduction set to get it down to an acceptable RPM for kids that can do a max of 100 RPM for short periods.

2. I improved the flipper design on the divider box, and my new design works much more reliably than the old.

The model is now ready for the grandkids to do an endurance test on it, and see how it holds up !!

Jan 1, 2023 Update

Model has survived kids for several sessions.

had a few kinks left in the model though.

1. on the chute where the middle gear discharges into the track, sometimes the marble would not fall off, then it would carry past the opening and then fall down.
    Solution: Widen exit spot on chute with Dremel.....seems to have fixed the problem.

2. every couple of revs, there is rough spot felt while cranking. traced it back to a couple of teeth between lower and middle gear not engaging nicely.
    Solution: Reduce teeth side with Dremel burr tool.

3. On lower wheel, there is one hole where the marble does not want to fall out by gravity when marble at top. For some reason, no taper on the hole??
    I'm pretty sure I drilled it right with fixture?
    Solution: tough to add material back. From back of gear, drilled 9/64" hole at angle down into hole, then put in short 1/8" dowel, to help force out marble.
        Will have to test this one out.